ANALYSIS OF SUSPENDED SEDIMENT, METALS, AND ARSENIC RELEASED TO THE CLARK FORK RIVER DURING A PIPELINE CROSSING EVENT

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Abstract

On April 1, 2000, Yellowstone Pipeline Company replaced a section of gas pipeline where it crosses under the Clark Fork River near Turah, MT. Due to heavy metals contamination of the river sediments from historic mining and smelting in the headwaters, the Department of Environmental Quality designed a sampling plan to monitor the water column during instream construction. Samples for total suspended sediments (TSS), hardness, and total recoverable Cu, Pb, Zn and As were collected 305 m and 1.68 km below the work, and 366 m upstream of the work. Integrated transect samples were collected in triplicate at each site using a hand-held depth integrating sampler. Samples were collected at all 3 sites the day prior to work, and then during 3 distinct work phases; trenching, pulling of the pipe across the channel, and burial. Samples were also collected 4 days after work began when no instream construction was occurring. During trenching, the material liberated to the river was very fine, as TSS concentrations 1.68 km below the work were equivalent to 305 m below. Furthermore, the MT acute aquatic life standard was slightly exceeded by Cu. After trenching and during pipe pulling, TSS concentrations dropped rapidly to background. Pipe burial commenced using the excavated material, and was completed using a borrow material (soil). The borrow material caused a large increase in TSS and raised the Cu concentration to 57.3 μg/L, a concentration similar to what is found at this site during runoff and further, exceeded the acute aquatic life standard by 2.5 times. The borrow material was much coarser than that of the river bottom, and mostly settled out before reaching the lowest site. By the 4^{th} day after work began, all instream concentrations had returned to pre-work values. Load calculations based on concurrent flow day indicated a total of 113.4 metric tons of suspended sediment were released to the river from the entire project. This value is an order of magnitude lower than typical daily TSS loads during Clark Fork high-flow events, but 5 times higher than background TSS during the construction. Among the various work procedures, burial contributed approximately 90% of the TSS load, followed in importance by trenching and pipe pulling.

Introduction

On April 1, 2000, Yellowstone Pipe Line Company replaced a section of gas pipeline where it crossed under the Clark Fork River near Turah, Montana. Replacement was necessary due to continual downcutting of the river at the location, which threatened to expose the existing pipe. Replacement involved digging a 3.1 m-deep trench into the riverbed, dragging a new section of pipe across, and reburying it. Water-column metals concentrations at this site frequently exceed state water quality standards, particularly copper (Cu; USGS 1997). Metals contamination is a legacy of 19^{th} and 20^{th} century mining near Butte, MT, where mine tailing was historically dumped into the Clark Fork River headwaters. These tailings have, over time, moved downstream and have been distributed in the bed sediments and floodplain of the river (Axtmann and Luoma 1991). Concerns raised over the potential release of water-borne metals during the trenching of the riverbed led the Department of Environmental Quality to conduct sampling during the instream construction process. Cu, lead (Pb), zinc (Zn), and arsenic (As) were selected as the most likely contaminants. Total suspended solids (TSS) were also sampled, as was hardness, which was used to calculate aquatic life standards (MT DEQ 1998). The primary objective of the study was to determine the extent of the impact, both from a loading and concentration perspective, resulting from this single instream construction event.

Methods and Materials

Sampling design-spatial and temporal layout. Samples were collected at 3 sites (A, B, C). Site A (upstream control) was located 366 m upstream from the crossing site, site B was located 305 m below the crossing site, and site C was located 1.68 km downstream of the crossing site (Fig. 1). Site C was sampled to determine the extent to which suspended material moved downstream. Sampling was undertaken the day prior to the channel cutting in order to determine the relative similarity of the 3 sites. The placing of the pipe then involved three work phases. The first phase was the cutting of a 3.1 m-deep trench into the river bottom perpendicular to river flow (herein referred to as "trenching"). Next, the pipe was pulled in its trench from the left bank to the right via a cable ("pipe pulling"). Finally, the pipe was reburied using the excavated material and additional material brought from a borrow area ("burial"). All 3 sites were sampled during each

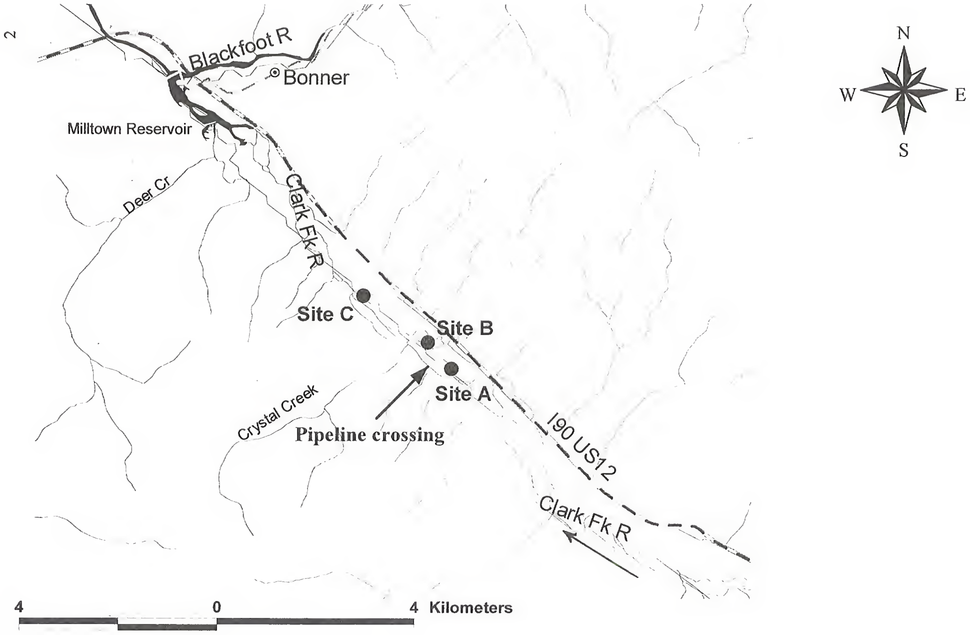


Fig. 1. Pipeline crossing site and location of 3 sampling sites on the Clark Fork River.

of these major work events, during the peak of work activity. Samples at the upstream control were collected as near in time as practical to the occurrence of a given work event. Site C was always sampled 40-50 min after site B, depending upon flow. At measured flows 40-50 min was appropriate to allow a given particle to travel from site B to C. The final set of samples was collected 4 days after the work was begun, at which time no instream work was occurring.

Sample collection and analysis. Three replicates were collected at each site during each sampling. A systematic sampling approach was used, each replicate being a composite of 20-25 subsamples collected at even intervals along a transect across the channel. Samples were collected using a depth integrating, isokinetic-nozzle sampler (model DH48; Edwards and Glysson 1999). This approach resulted in a sample of approximately 2 liters per replicate, each replicate taking approximately 5 min to collect. Each sample was analyzed for total recoverable Cu, Pb, Zn, and As, as well as hardness and TSS. All sample bottles were acid washed/distilled-water rinsed prior to use, while the DH48 sampler was acid washed/distilled-water rinsed when taken between sites, and between work events. A field-equipment blank was collected at site C. Samples were iced and held in the dark (3 days maximum) until delivered to the Montana Environmental Laboratory (Helena, MT) for analysis. Dissolved oxygen, temperature, conductivity, and pH were also measured at site B using a hand-held meter. Ca, Mg, Cu and Zn were analyzed using EPA method 200.7. The reporting value for Cu was 1 μg/L, for Zn, 5 μg/L. Pb and As were analyzed via EPA method 200.9, each with a reporting value of 1μg/L. TSS was analyzed using EPA method 160.2, with a reporting value of 1 mg/L.

A mean and standard deviation was calculated for each analyte. Although sampling was systematic rather than randomized, the formulas for estimating sample statistics were identical to those that would be used for a randomized sampling. This approach is applicable when the sampled population exists in a random order (Cochran 1977), which was most likely the case in this study.

Load approximations. Metals, As and TSS loading to the Clark Fork River was calculated using USGS flow-data from the Turah Bridge station, which was available on the USGS website. The Turah gauge station is located between sites A and B. For each calculation, the replicate mean for a given analyte was used as the instream concentration. Gross load during a given work

event (i.e., trenching) for a given site was calculated as: [work duration (hr)] • [conc. (mg/L) • flow (L hr^{-1})]. Net load (i.e., load attributable only to the instream work) for each work event was calculated as: [gross load site B]-[gross load site A].

Results

Total suspended sediments. Relative concentration changes are shown in Fig. 2. Ambient instream TSS averaged 11.0 mg/L the day prior to the work, with all three sites demonstrating very similar values. However, there was a three-fold or greater increase in TSS at sites B and C during both the trenching and day-1 burial processes (Fig. 2). Pipe pulling was commenced within 35 minutes of the completion of the trenching process, and at that time TSS concentrations at site B (305 m downstream from the work) had already dropped back to ambient concentrations. Burial of the pipe on day 2 resulted in the highest TSS measured during the sampling (mean: 133 mg/L). The material used at the time was not river bottom sediments, but rather loose soil brought in from a borrow area (presumably in the nearby floodplain). In spite of the relatively high concentration of TSS at site B during burial (day 2), the TSS concentration at site C (27.4 mg/L) was much closer to ambient than had been observed during day-1 burial (Fig 2). When sampled four days after the work first began, all TSS concentrations had returned to pre-work values (Fig. 2). No TSS was detected in the field equipment blank.

Heavy metals and arsenic. Metals and arsenic are shown in Fig. 3A-D. As was the case for TSS, all three sites has similar concentrations the day prior to work commencement, with the exception of Pb, which was much higher at site B. There were no metals or As detected in the field equipment blank.

At no point in the study was any human-health drinking standard violated. The acute aquatic life standard is shown in the figures as three horizontal lines. The solid line is the standard calculated from the mean hardness for the entire study period, while the dashed lines represent the standard calculated from the lowest and highest hardness measured during the study. Cu was the only element that demonstrated significant violations of applicable water quality standards (Fig 3A). The acute aquatic life standard for Cu was exceeded at site C during pipe trenching, and was clearly exceeded during burial (day 2) at site B, by a factor of 2.5.

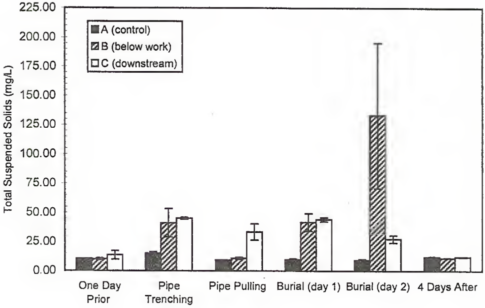


Fig. 2. Total suspended sediment concentrations in the Clark Fork River during a pipeline crossing. Error bars are one standard deviation of the mean.

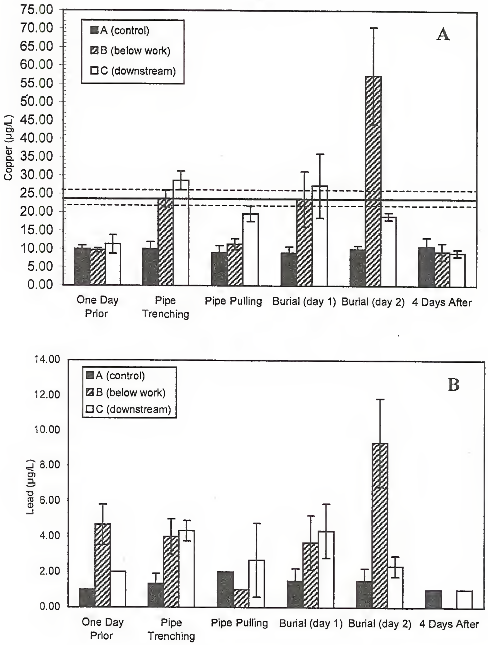
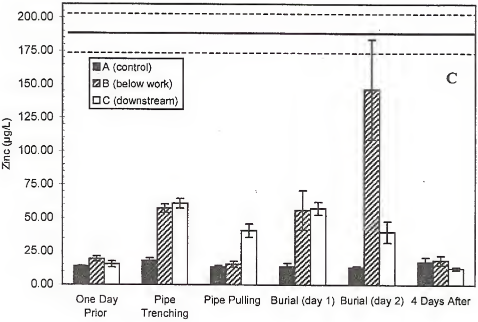


Fig. 3. Heavy metal and arsenic concentrations in the Clark Fork River during a pipeline crossing. A. total recoverable copper. B. Total recoverable lead. Error bars are one standard deviation of the mean. Horizontal lines represent aquatic life standard at the mean, minimum, and maximum hardness measured during the study.



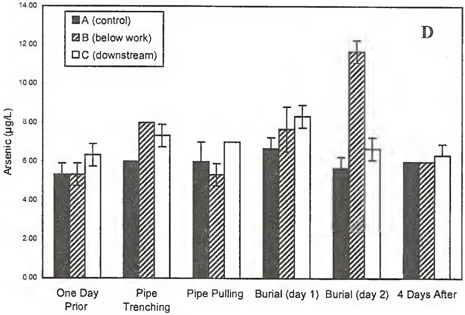


Fig. 3, Continued. C. Total recoverable zinc. D. Total recoverable arsenic.

Standards were probably also exceeded at site B (trenching), and at B & C (burial day-1), although the greater variability in replication diminishes confidence in these measurements.

Pb demonstrated quite variable concentrations throughout the sampling, with only one clear increase as a result of the instream work (site B; burial day-2). Throughout the study the acute aquatic life Pb standard (162 μg/L) was never approached (Fig. 3B). Zn showed clear increases as a result of instream work, however only during burial (day 2) at site B may the aquatic life standards have been exceeded (Fig 3C). Arsenic showed the smallest relative increase as a result of instream work, and concentrations remained below all applicable standards (Fig. 3D).

Water quality measurements collected by meter are shown in Table 1. During collection of the trenching measurements, there was a clearly observable increase in turbidity resulting from the work. However, there were no notable changes in any of the water quality parameters that were measured.

Load estimates. Loads of TSS, metals and As were similar at all sites prior to the pipeline crossing, and after work was completed (Table 2). Gross and net contributions of material to the river are shown in Tables 3 and 4. The smallest net contributor was the pipe pulling, while the largest contributor (by far) was burial on day 2, as a result of increased flows, longer work duration, and higher instream concentrations. There was actually a negative contribution from pipe pulling (Table 4), as the concentrations at site B were lower than at the upstream control (site A) at that time.

Discussion

Suspended sediments, metals, and arsenic. During construction, the river-bottom sediments were placed in a large pile in midstream. The river bottom was primarily a course material comprised of cobble and gravel, with limited fine material (personal observation). The project engineer stated that using a mid-channel pile had been found to minimized TSS loading at other crossings (C. Uselmann, personal communication). This is supported by the rapid change in TSS at site B after trenching was completed. The pipe pulling samples were collected approximately 1 hr after trenching was completed and, in spite of the pulling process, TSS had already returned

Table 1. Water quality measurements made on April 1, 2000, during the pipeline crossing.

	Time	Dissolved O_2 (mg/L)		Temp. (° C)		pH		Cond. (μs cm^{-1})	
	(range)	Site A	Site B	Site A	Site B	Site A	Site B	Site A	Site B
Prior to trenching	6:45-7:50 am	11.5	11.9	6.6	6.5	7.4	7.5	310	349
Trenching	1:37am-12:55 pm	13.1	13.0	7.6	7.1	8.0	7.7	373	330
Between pulling & burial	3:50 pm		12.8		8.3		8.2		325

Table 2. Load of suspended sediment, Cu, Pb, Zn and As prior to, and after, pipeline crossing.

	One Day Prior to Crossing		Four Days after Start of Work	
	Concentration (mg TSS or µg /L)	Load† (kg/hour)	Concentration (mg TSS or µg /L)	Load† (kg/hour)
Site A				
TSS	10.3	811.5	11.8	1142.9
Cu	10.0	0.8	10.7	1.0
Pb	1.0	0.1	1.0	0.1
Zn	13.7	1.1	17.0	1.7
As	5.3	0.4	6.0	0.6
Site B				
TSS	9.2	726.9	10.9	1058.6
Cu	9.7	0.8	9.3	0.9
Pb	4.7	0.4	nd	----
Zn	19.3	1.5	18.3	1.8
As	5.3	0.4	6.0	0.6
Site C				
TSS	13.5	1069.0	11.9	1149.7
Cu	11.3	0.9	9.0	0.9
Pb	2.0	0.2	1.0	0.1
Zn	15.3	1.2	12.3	1.2
As	6.3	0.5	6.3	0.6
Mean of sites				
TSS	11.0	869.1	11.5	1117.1
Cu	10.3	0.8	9.7	0.9
Pb	2.6	0.2	1.0	0.1
Zn	16.1	1.3	15.9	1.5
As	5.7	0.4	6.1	0.6

†Based on flows measured at the Turah Bridge USGS guaging station at time of sampling.

Table 3. Loading of TSS, Cu, Pb, Zn and As associated with different work events of the pipeline crossing.

		TSS		Cu		Pb		Zn		As	
	Work duration (hours)	Load† (Kg/hr)	Gross load‡ (Kg)	Load† (Kg/hr)	Gross load‡ (Kg)	Load† (Kg/hr)	Gross load‡ (Kg)	Load† (Kg/hr)	Gross load‡ (Kg)	Load† (Kg/hr)	Gross load‡ (Kg)
SITE A (control)											
Trenching	5	1229.0	6146.0	0.82	4.1	0.11	0.5	1.47	7.3	0.49	2.4
Pulling	2	756.0	1512.0	0.73	1.5	0.16	0.3	1.10	2.2	0.49	1.0
Burial (day 1)	2.5	777.0	1943.0	0.73	1.8	0.12	0.3	1.11	2.8	0.54	1.4
Burial (day 2)	8*	878.5	7028.0	0.97	7.7	0.15	1.2	1.26	10.1	0.55	4.4
TOTAL:	***17.5***		***16629.0***		***15.1***		***2.3***		***22.4***		***9.2***
SITE B											
Trenching	5	3349.7	16749.0	1.93	9.7	0.33	1.6	4.68	23.4	0.65	3.3
Pulling	2	872.7	1745.0	0.92	1.8	0.08	0.2	1.25	2.5	0.43	0.9
Burial (day 1)	2.5	3403.6	8508.9	1.93	4.8	0.30	0.7	4.57	11.4	0.63	1.6
Burial (day 2)	8*	12881.6	103053.0	5.55	44.4	0.90	7.2	17.20	113.4	1.13	9.0
TOTAL:	***17.5***		***130055.9***		***60.7***		***9.7***		***150.7***		***14.8***
SITE C											
Trenching	5	3670.3	18351.0	2.34	11.7	0.35	1.8	4.98	24.9	0.60	3.0
Pulling	2	2732.3	5464.6	1.60	3.2	0.22	0.4	3.32	6.6	0.57	1.1
Burial (day 1)	2.5	3588.7	8972.0	2.23	5.6	0.35	0.9	4.68	11.7	0.68	1.7
Burial (day 2)	8*	2653.8	21231.0	1.84	14.7	0.23	1.8	3.84	30.7	0.65	5.2
TOTAL:	***17.5***		***54018.6***		***35.2***		***4.9***		***73.9***		***11.0***

† Based on flows measured at the Turah Bridge USGS guaging station at time of sampling.

‡ Calculated as the product of work duration and hourly load.

*Estimated.

Table 4. Net contribution of TSS, Cu, Pb, Zn and As to the Clark Fork River resulting from pipeline crossing.

	TSS[†] (Kg)	Cu[†] (Kg)	Pb[†] (Kg)	Zn[†] (Kg)	As[†] (Kg)
Trenching	10603	5.6	1.1	16	0.8
Pulling	233	0.4	-0.2	0.3	-0.1
Burial (day 1)	6566	3.0	0.4	8.6	0.2
Burial (day 2)	96025	36.7	6.1	103.3	4.6
TOTAL (metric tons)	113.4	0.046	0.007	0.128	0.006

[†]Calculated as the difference between site B (305 m below work site) and site A (upstream control).

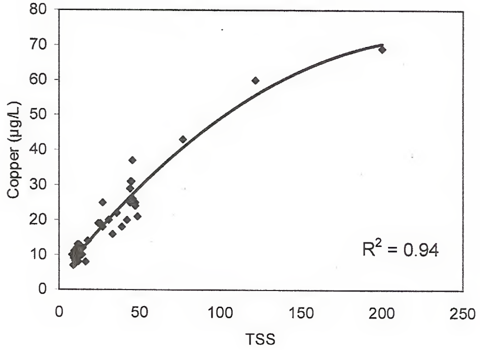
to ambient concentration at site B (Fig. 2). The high TSS concentration at site C during the pipe pulling was residual material from the trenching process that had not completely moved downstream. The materials that were carried downstream during the trenching process were evidently quite fine, as the TSS concentration over 1.5 km downstream from the work site (at site C) was equal to that found just 305 m below it (Fig 2).

Metals can be released to the river water column in association with particles as well as in solution (Brick and Moore 1996). This study's results indicate a strong association between TSS and metals or As (Fig. 4). The relationships tend to be curvilinear, which may be the result of differing properties of the river bottom sediment vs. the borrow material. The highest TSS datapoints are associated with sampling that took place when the main source of TSS was borrow material.

Among the elements measured, Cu was the only one that significantly violated applicable standards. The high concentration of Cu released during burial (day 2) appears to be the result of contaminated fill material brought to the site, presumably from the floodplain. The material also contained elevated concentrations of Pb, Zn and As, and was probably material from upriver which had been deposited in the floodplain during a high-flow event. The total recoverable Cu concentration (57.3 μg/L) that occurred as a result of day-2 burial was equal to the mean total Cu concentration at the Turah site from 1985-1996 (53 μg/L; Dodge et al. 1997). Further, it was an order of magnitude lower than the highest total Cu concentration (500 μg/L) measured during those years, and was equivalent to concentrations measured during high flow at the Turah site in 1987 (Lambing 1989).

In addition to having elevated metals concentrations, the borrow material was much courser than that of the stream bottom. TSS dropped much more rapidly between sites B and C relative to what was observed during trenching (Fig 2). By the fourth day after work began, all instream concentrations had returned to that found prior to work commencement (Fig. 3A-D).

Loading to the river. The calculation used to determine loading to the river probably resulted in a high estimate, as samples representing a work event were only collected at the *peak* of activity. Therefore, there was a significant amount of time prior to and after collection when concentrations may have been lower than those measured. These calculations, therefore, should be viewed as a worst-case scenario. The total or net contribution of TSS during the entire project



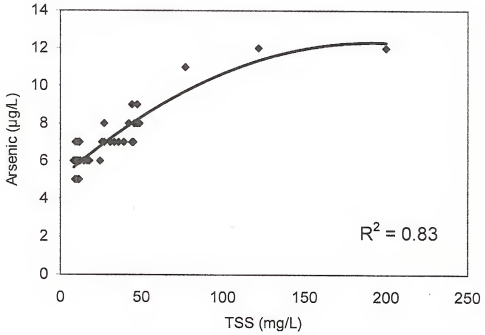


Fig. 4. Relationship between total suspended solids and total recoverable copper and arsenic. Trendline is a 2nd order polynomial.

was estimated as 113.4 metric tons (Table 4). Of this, 90% was a result of the burial process, including the borrow material brought to the river. The total contribution of 113.4 metric tons was very close to that predicted in the Environmental Assessment (109 metric tons; MT DEQ 1999). To put this number in perspective, TSS during runoff often reaches 1,500 metric tons day^{-1}, and can be many times higher (Lambing et al. 1994; Dodge et al. 1997). The mean TSS load for the river at Turah from 1985-1993 was 728 metric tons day^{-1} (Lambing et al. 1994), while the mean ambient sediment-load in the Clark Fork River measured during this study was 22.4 metric tons day^{-1}. The TSS released from the entire crossing event was more than an order of magnitude lower than that that could be expected during a single day of a typical runoff event, six times lower than the average river TSS load, but still notably higher than background during the construction.

Conclusions

Pipeline crossings events such as this are common occurrences throughout Montana. These data should aid in making future permitting efforts more accurate. In this study, TSS concentrations were found to be closely associated with metals ($R^2 > 0.90$). During trenching, the Cu aquatic life standard was slightly exceeded 1.5 km downstream from the work site. Furthermore, the material liberated during trenching was evidently quite fine, as concentrations of TSS, metals and As more than 1.5 km downstream from the work site were equal to or greater than concentrations just 305 m downstream. However, TSS concentrations dropped rapidly (in less than 1 hr) after trenching was completed, and remained low during the pipe pulling. Pipe burial again elevated TSS and metals concentrations, however it was the borrow material brought in to complete burial which contributed the greatest amount of TSS, metals and As. This material contributed the highest amount (mean: 133 mg/L) of TSS to the river, and caused the highest Cu concentration to be measured in the study (57.3 μg/L). This Cu concentration was similar to that which is found at this site during runoff, and caused a significant (2.5-fold) violation of the Cu aquatic life standard. The borrow material differed from the river bottom sediments in that it was larger and settled out much more quickly. The last samples were collected 4 days after work was commenced, at which time no instream work was occurring. Concentrations at this time were equivalent to those collected the day prior to the start of work.

Net TSS loading during the entire construction effort was estimated at 113.4 metric tons. This value is an order of magnitude lower than a single day's TSS load during a commonly occurring runoff event in the Clark Fork River, but equivalent to 5 days of sediment load at the background concentration measured during this study (22.4 metric tons day^{-1}). In order of greatest contribution of metals, As and TSS loading to the river, the work events rank as pipe burial (including use of borrow material), trenching, and pipe pulling.

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APPENDIX A

Table of replicate analyte data collected for

Yellowstone Pipeline crossing of the Clark Fork River

Appendix A. Table of replicate analyte data collected for Yellowstone Pipeline Crossing of Clark Fork River.

Sample naming convention:

- *A* Site.
- *0* Day since work began.
- *W* "work"; refers to following letter designation:
- *N* N= no work, T = trenching, P = pipe pulling, B = burial.
- *R1* replicate number.

Day	Sample	TSS† (mg/L)	Total Hardness† (mg/L as $CaCO_3$)	Copper (TR)† µg/L	Lead (TR)† µg/L	Zinc (TR)† µg/L	Arsenic (TR)† µg/L
0	A0WN R1	10.4	174	11	1	14	5
0	A0WN R2	10.4	176	10	1	13	5
0	A0WN R3	10	175	9	1	14	6
	Mean	**10.27**	**175.00**	**10.00**	**1.00**	**13.67**	**5.33**
	1 standard deviation	0.23	1.00	1.00	0.00	0.58	0.58
0	B0WN R1	10.8	172	9	6	17	6
0	B0WN R2	9.2	168	10	4	21	5
0	B0WN R3	9.75	171	10	4	20	5
	Mean	**9.92**	**170.33**	**9.67**	**4.67**	**19.33**	**5.33**
	1 standard deviation	0.81	2.08	0.58	1.15	2.08	0.58
0	C0WN R1	11	172	9	nd	14	6
0	C0WN R2	11.8	168	11	2	14	7
0	C0WN R3	17.8	168	14	nd	18	6
	Mean	**13.53**	**169.33**	**11.33**	**2.00**	**15.33**	**6.33**
	1 standard deviation	3.72	2.31	2.52	-----	2.31	0.58
1	A1WT R1	16.40	172.00	8.00	1.00	16.00	6.00
1	A1WT R2	14.21	177.00	10.00	2.00	18.00	6.00
1	A1WT R3	14.60	181.00	12.00	1.00	20.00	6.00
	Mean	**15.07**	**176.67**	**10.00**	**1.33**	**18.00**	**6.00**
	1 standard deviation	1.17	4.51	2.00	0.58	2.00	0.00
1	B1WT R1	27.00	187.00	25.00	3.00	55.00	8.00
1	B1WT R2	47.40	176.00	25.00	5.00	61.00	8.00
1	B1WT R3	48.80	175.00	21.00	4.00	56.00	8.00
	Mean	**41.07**	**179.33**	**23.67**	**4.00**	**57.33**	**8.00**
	1 standard deviation	12.20	6.66	2.31	1.00	3.21	0.00
1	C1WT R1	44.20	178.00	29.00	5.00	57.00	7.00
1	C1WT R2	45.00	179.00	31.00	4.00	64.00	7.00
1	C1WT R3	45.80	177.00	26.00	4.00	62.00	8.00
	Mean	**45.00**	**178.00**	**28.67**	**4.33**	**61.00**	**7.33**
	1 standard deviation	0.80	1.00	2.52	0.58	3.61	0.58

Day	Sample	TSS† (mg/L)	Total Hardness† (mg/L as $CaCO_3$)	Copper (TR)† µg/L	Lead (TR)† µg/L	Zinc (TR)† µg/L	Arsenic (TR)† µg/L
1	A1WP R1	9.40	178.00	11.00	nd	12.00	6.00
1	A1WP R2	9.00	169.00	7.00	2.00	14.00	5.00
1	A1WP R3	9.40	174.00	9.00	2.00	14.00	7.00
	Mean	**9.27**	**173.67**	**9.00**	**2.00**	**13.33**	**6.00**
	1 standard deviation	0.23	4.51	2.00	0.00	1.15	1.00
1	B1WP R1	10.00	171.00	11.00	1.00	18.00	5.00
1	B1WP R2	11.60	172.00	13.00	nd	14.00	5.00
1	B1WP R3	10.50	178.00	10.00	nd	14.00	6.00
	Mean	**10.70**	**173.67**	**11.33**	**1.00**	**15.33**	**5.33**
	1 standard deviation	0.82	3.79	1.53	------	2.31	0.58
1	C1WP R1	35.80	175.00	22.00	5.00	46.00	7.00
1	C1WP R2	39.10	175.00	18.00	1.00	40.00	7.00
1	C1WP R3	25.60	169.00	19.00	2.00	36.00	7.00
	Mean	**33.50**	**173.00**	**19.67**	**2.67**	**40.67**	**7.00**
	1 standard deviation	7.04	3.46	2.08	2.08	5.03	0.00
1	A1WB R1	8.80	173.00	7.00	1.00	14.00	6.00
1	A1WB R2	9.40	176.00	10.00	2.00	11.00	7.00
1	A1WB R3	10.40	176.00	10.00	nd	16.00	7.00
	Mean	**9.53**	**175.00**	**9.00**	**1.50**	**13.67**	**6.67**
	1 standard deviation	0.81	1.73	1.73	0.71	2.52	0.58
1	B1WB R1	33.20	177.00	16.00	2.00	40.00	7.00
1	B1WB R2	47.40	172.00	24.00	4.00	59.00	9.00
1	B1WB R3	44.60	174.00	31.00	5.00	69.00	7.00
	Mean	**41.73**	**174.33**	**23.67**	**3.67**	**56.00**	**7.67**
	1 standard deviation	7.52	2.52	7.51	1.53	14.73	1.15
1	C1WB R1	45.60	175.00	37.00	6.00	59.00	8.00
1	C1WB R2	44.20	175.00	25.00	4.00	61.00	9.00
1	C1WB R3	42.20	174.00	20.00	3.00	52.00	8.00
	Mean	**44.00**	**174.67**	**27.33**	**4.33**	**57.33**	**8.33**
	1 standard deviation	1.71	0.58	8.74	1.53	4.73	0.58
2	A2WB R1	9.20	173.00	9.00	1.00	14.00	5.00
2	A2WB R2	8.20	172.00	10.00	nd	12.00	6.00
2	A2WB R3	9.80	173.00	11.00	2.00	13.00	6.00
	Mean	**9.07**	**172.67**	**10.00**	**1.50**	**13.00**	**5.67**
	1 standard deviation	0.81	0.58	1.00	0.71	1.00	0.58

Day	Sample	TSS† (mg/L)	Total Hardness† (mg/L as $CaCO_3$)	Copper (TR)† µg/L	Lead (TR)† µg/L	Zinc (TR)† µg/L	Arsenic (TR)† µg/L
2	B2WB R1	122.00	170.00	60.00	9.00	139.00	12.00
2	B2WB R2	200.00	175.00	69.00	12.00	187.00	12.00
2	B2WB R3	77.00	176.00	43.00	7.00	113.00	11.00
	Mean	**133.00**	**173.67**	**57.33**	**9.33**	**146.33**	**11.67**
	1 standard deviation	62.23	3.21	13.20	2.52	37.54	0.58
2	C2WB R1	30.80	174.00	20.00	3.00	47.00	7.00
2	C2WB R2	24.40	167.00	19.00	2.00	31.00	6.00
2	C2WB R3	27.00	165.00	18.00	2.00	41.00	7.00
	Mean	**27.40**	**168.67**	**19.00**	**2.33**	**39.67**	**6.67**
	1 standard deviation	3.22	4.73	1.00	0.58	8.08	0.58
2	*Equipment blank (site C)*	nd	nd	nd	nd	nd	nd
4	A4WN R1	12.20	166.00	13.00	1.00	21.00	6.00
4	A4WN R2	11.60	162.00	11.00	nd	14.00	6.00
4	A4WN R3	11.60	159.00	8.00	nd	16.00	6.00
	Mean	**11.80**	**162.33**	**10.67**	**1.00**	**17.00**	**6.00**
	1 standard deviation	0.35	3.51	2.52	-----	3.61	0.00
4	B4WN R1	11.00	155.00	8.00	nd	18.00	6.00
4	B4WN R2	11.00	161.00	12.00	nd	22.00	6.00
4	B4WN R3	10.80	157.00	8.00	nd	15.00	6.00
	Mean	**10.93**	**157.67**	**9.33**	------	**18.33**	**6.00**
	1 standard deviation	0.12	3.06	2.31	------	3.51	0.00
4	C4WN R1	11.80	160.00	8.00	nd	13.00	6.00
4	C4WN R2	11.60	158.00	9.00	1.00	13.00	7.00
4	C4WN R3	12.20	164.00	10.00	nd	11.00	6.00
	Mean	**11.87**	**160.67**	**9.00**	**1.00**	**12.33**	**6.33**
	1 standard deviation	0.31	3.06	1.00	------	1.15	0.58

† "nd" indicates value was below: 1 µg/L for Cu, Pb & As; 5 µg/L for Zn; 1 mg/L for TSS; and 100 µg/l for hardness.

APPENDIX B

Table of flow data used in loading calculations

Appendix B. Table of flow data used in loading calculations.
From USGS website for Clark Fork River at Turah (Station 12334550).

	Flow (ft^3 sec^{-1})		
	Site A	Site B	Site C
3/31/00 (Day 0)	775	775	775
4/1/00 (Day 1)	800	800	800
4/4/00 (Day 4)	950	950	950